Reducing Environmental Impacts: Aluminium Recycling

Case Study

Recycling of Aluminum Can in Terms of Life Cycle Inventory (LCI)*

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Abstract

Background, Aims and Scope. Life Cycle Assessment is a technique for evaluating the environmental performance of a given product by: identifying and quantifying the energy and raw materials used in its manufacturing process, as well as the emissions of pollutants to water, soil, and air inherent in this production, use and disposal, and evaluating the environmental impact associated with the use of energy and materials and the emissions of pollutants, thus identifying opportunities to improve the system in order to optimize the environmental performance of the product. CETEA (Packaging Technology Center) has conducted a Life Cycle Assessment – LCA study of aluminum can with emphasis in life cycle inventory, collecting data for the reference years 2000–2002. The goal of this paper is to present part of this complete study, focusing the influence of aluminum recycling rate on the Life Cycle Inventory (LCI) of aluminum beverage cans in Brazil.

Methods. The adopted methodology was based on the recommendations of SETAC – Society of Environmental Toxicology and Chemistry and the ISO 14040 Standard, approved by the Sub-Committee 05 of the Environmental Administration Technical Committee, TC-207, from ISO – INTERNATIONAL ORGANIZATION FOR STANDARDIZATION [1,2]. Data storage and modeling were performed by employing the PIRA Environmental Management System – PEMS [3].

Results. Taking into account the impact categories adopted in this study, it has been shown that recycling helps to improve the aluminum can environmental profile measured as LCI data.

Discussion. For the transformed aluminum products, the recycling rate affects the values of the environmental parameters inventoried, but not in the same proportion, since the contribution of other stages of the product system life cycle and the recycling process remain unchanged, including the yield of this process. In general, the recycling balance is always positive due to the importance of the stages that precede the packaging production and the problem of increasing the municipal waste volume.

Conclusions. The advantages of the recycling are obviously concentrated on the inventoried parameters related to the primary aluminum production and to the package disposal. The verified benefits of the recycling increase with the recycling rate enhancement. However, the effects on the inventory do not have the same magnitude of the recycling rate. This happens due to the relative contributions of the other life cycle stages, such as the transportation and sheet or can production. In agreement with the presented results, it is possible to conclude that the aluminum can recycling reduces part of the consumption of natural resources and the emissions associated to the stages previous to the production of the packaging. The parameters specifically related to the stage of aluminum production suffer reduction directly proportional to the increase of the recycling rate. In this way, all of the efforts made to increase the recycling rate will have a positive contribution to the LCI of the aluminum can.

Recommendations. It is worth pointing out that LCA studies are iterative and dynamic. The data can always be refined, substituted or complemented with updated information in order to improve the representativeness of the analyzed sector.

Perspectives. From this study, the aluminum sector in Brazil is able to quantify the benefits of future actions for environmental improvement of the Brazilian aluminum industry, as well as to contribute technically to Environmental Labeling initiatives regarding aluminum products.

Keywords: Aluminum; Brazil; can; electricity; energy; environment; inventory; life cycle assessment; recycling

Introduction

This project was developed aiming at the interpretation of Brazilian aluminum cans employing the Life Cycle Assessment technique, considering the conditions and the technological level of the country.

Brazil recycled 89% of total aluminum cans sold in 2003, in 2004–2005 this index was 96%. With this index, the country stands out as world leader in the recycling of aluminum cans, for the fourth consecutive year, considering the nations where this activity is not obligatory by law [4].

The index of 89% corresponded to the 112,000 tons of aluminum cans or approximately 8.2 billion units [4].

Background-data of all the inputs and outputs from the system have been inventoried as follows: bauxite, alumina, primary aluminum, aluminum sheet, can, recycling, emissions to air / water, process waste, used fuel and electricity (public and/or private hydroelectric), efficiency and land use. Models for Electric Energy Generation, Fuel Production, Fuel Combustion and Load Transportation in Brazil developed by CETEA for LCA of products were used in order to build up the Life Cycle Inventories. The aim of the complete study was to represent the Brazilian average situation of produc-

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tion and recycling relative to aluminum DWI (Drawn and Wall Ironing) can, capacity 350 mL. For generating the Brazilian average data of bauxite, alumina, primary aluminum, aluminum sheet and can, the data were compiled taking into account 100% of the companies involved in each phase of the production process, considering products consumed in Brazil. After the company agreed to collaborate with the project, appropriate questionnaires were prepared and sent to data collection and fulfilled. The companies were responsible for both collecting the data and completing the data sheets. The calculation of the Brazilian average aluminum recycling was accomplished considering the data supplied by the following companies and technologies:

- Technology 1 – two companies whose aluminum recycling plants use as raw materials only post-consumer aluminum cans, cans derived from the production losses in the can factories (process scraps and retails) and losses derived from the beverage industries, and
- Technology 2 – a third company that uses all kinds of aluminum scraps, including cans in its recycling process, representing generically the recycling processes.

Both technologies described above were analyzed in the proportion 50% technology 1 plus 50% technology 2 and they are considered representative of the sector. In both technologies, the recycled aluminum production process is divided into two stages: the cold and hot areas. The cold area consists of passing the cans that arrive from the collection sites or scrapers in pressed bales through an unpacking for breaking the blocks and then through a knife mill for separation of the cans that will pass through a magnetic separator. After this first separation, a hammer mill perforates and transforms the cans into chips that pass again through a magnetic separator, followed by a screen for dirt removal like earth and sand and, later, through a pneumatic separator for separation of light and heavy materials. In the hot area, the material prepared in the previous stage passes through a rotary oven, for varnish and ink removal, before it enters the melting oven where the aluminum scrap is converted into liquid metal. The liquid metal is then transferred to melting pots, which are transported to the sheet plant. This process can cause air emissions as volatile organic compounds, particulate, nitrogen oxides, carbon monoxide and chlorides, water emissions as metals, oils and greases, aside from solid wastes. **Fig. 1** shows a simplified flow chart of the aluminum can life cycle, detailing the aluminum recycling process. It is important to emphasize that the amount of coatings, inks and compounds present in the can, as well as the oxidized portion of the metallic surface and the inherent process losses were accounted for as solid waste (output).

1 Goal and Scope

The complete study had as an objective conducting an LCA with emphasis on Life Cycle Inventory Analysis, for the aluminum DWI (Drawn and Wall Ironing) can, capacity 350 mL, representing the average Brazilian production and marketing share.

The benefits intended with the development of this study were:

- to know the relevant parameters and related environmental impacts associated with the aluminum packages' life cycle stages;
- to be a promoter of improvements for the aluminum package systems;
- to have a reference for future comparisons, in order to evaluate the evolution of the sector;
- to have available information to the customers that want to obtain an Environmental Label for their products;
- to evaluate the benefits of the post-consumer can recycling.

The aim of the study was to represent the Brazilian average situation of production and recycling relative to that product (aluminum DWI can). Therefore, the results do not refer to a single production process, but to the average situation of the analyzed product system, taking into account data collected in 100% of the Brazilian industries related to the aluminum can life cycle.

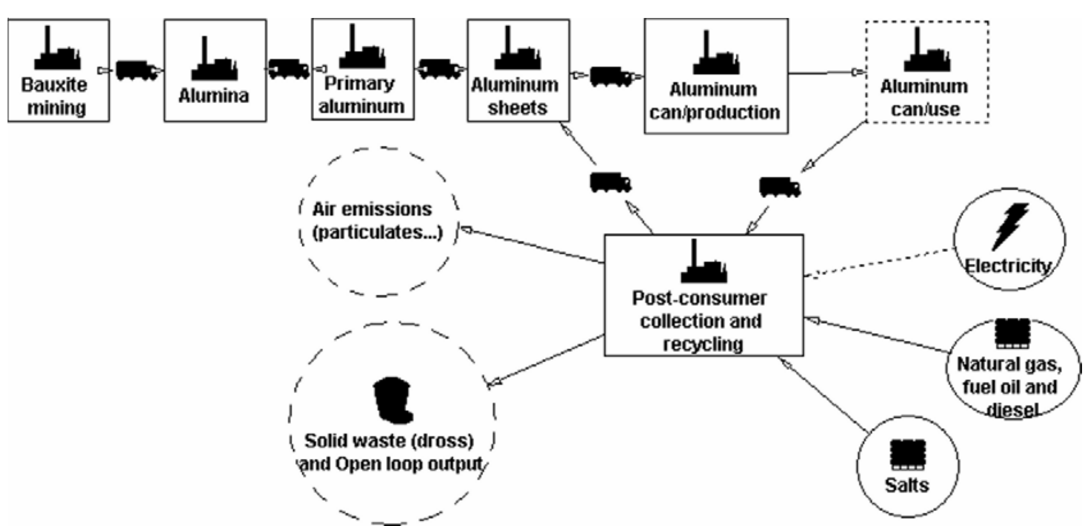

Fig. 1: Flow chart of the aluminum can production system, including the close loop recycling stage

The goal of this paper is to present part of this complete study, focusing the influence of aluminum recycling rate on the Life Cycle Inventory (LCI) of aluminum beverage cans in Brazil.

The adopted functional unit (1,000 kg of cans) refers to the amount of cans ready to be delivered to the beverage industry, but considering the post consumer stage, including the can collection and a close loop recycling, as detailed in Fig. 1.

Nine impact categories considered relevant for the Brazilian situation were selected in order to orient the data collection [5]. They are the following: consumption of natural resources; climate changes (greenhouse effect); acidification; nutrification / eutrophication; photochemical smog; human toxicity; ecotoxicity; use of landfill volume; land use.

Products, processes and energy production and transport systems were evaluated in a manner so as to reflect the average situation throughout the Brazilian territory. In the case of imported raw materials, average values were collected from published literature. Exports were not taken into account.

The stages related to the production of alloy elements employed in the manufacture of aluminum sheets (used in the production of the cans and ends) were not considered within the boundaries of the study (they represent 7% and 5% (w/w) of the end and the can sheet composition, respectively). Nevertheless, the transportation stages of those materials from their source to the production plants were included, taking into account the distances informed by the companies. Those elements were quantified as 'other mineral reserves'.

The electric energy generation data refer to the reference year 2000 [6].

2 Materials and Methods

Fig. 2 illustrates the boundaries defined for the complete study.

Fig. 2 clearly shows that each product was analyzed starting from the extraction of the natural resources from the earth: bauxite, oil, natural gas, coal, etc.

Partial life cycle inventories related to important stages, such as electric energy generation, road transportation and pre-combustion were incorporated in the LCA Inventories.

All the transportation stages were included within the boundaries of the system. Whenever it was known that the truck used to transport goods between the units processes returned empty, the distance covered by the loaded truck was double-counted.

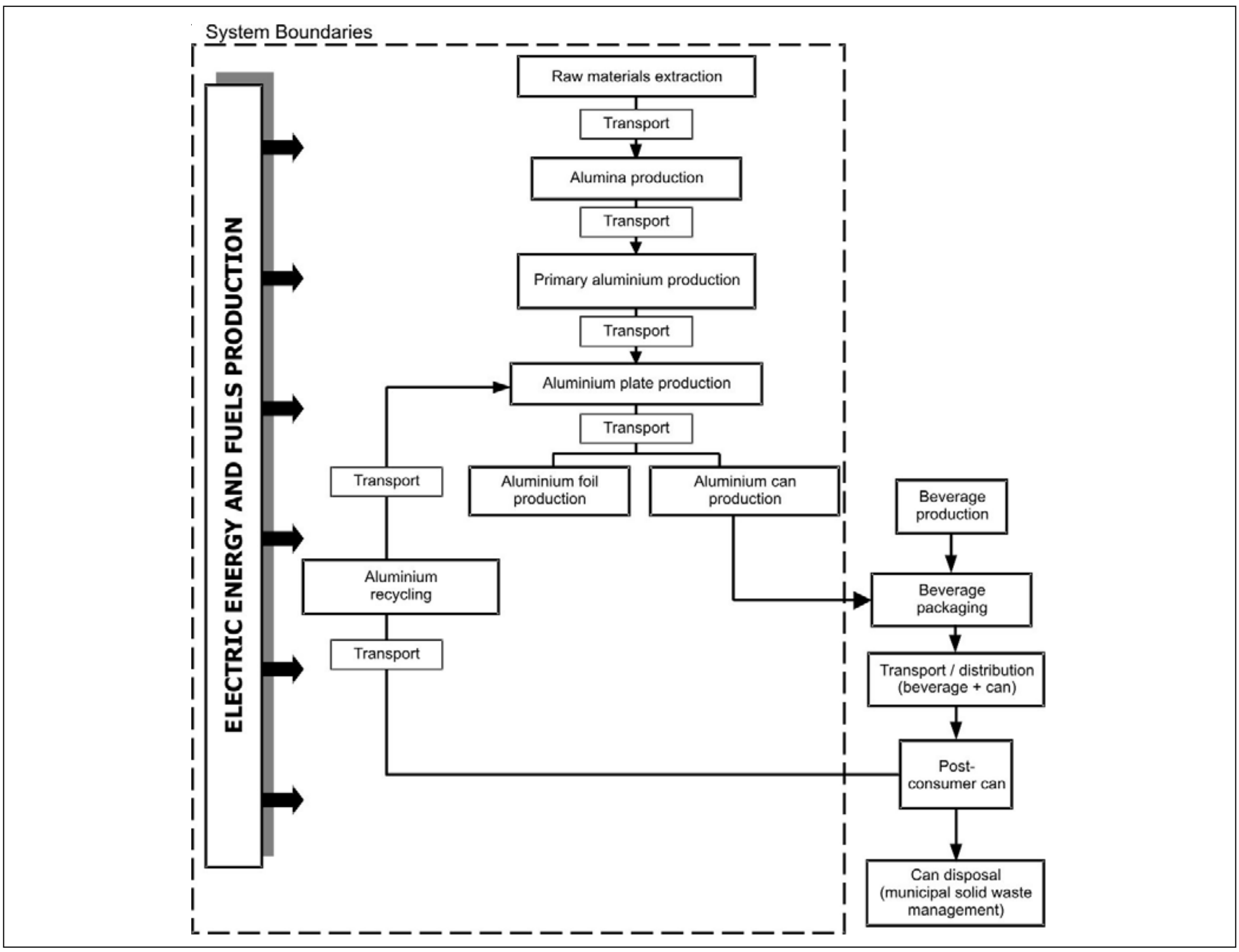

Fig. 2: Schematic representation of the boundaries of the study

The system boundaries encompass the main aspects (consumption and emission rates) relative to the extraction and production of fossil fuels (pre-combustion), such as diesel, fuel oil, coal, natural gas and liquefied petroleum gas – LPG. However, the transportation of the diesel from the refinery up to the gas stations that further distribute the diesel used for regular road transport of goods was not taken into account.

Printing inks, lacquers, compounds, additives, pigments and lubricants were only considered as to the consumption of energy and air emissions associated with their application or drying process. These components were quantified and identified such as 'other inputs'.

Treatments applied to the beverage prior to or after the filling procedure were excluded from boundaries as well as the secondary package's production and use. Only the average transport distances to deliver lids and empty cans to the beverage producer were considered.

Solid waste materials inherent to industrial processes were quantified and aggregated in the category 'Process waste', except those specific to the alumina and aluminum processes, i.e. 'red mud' and 'spent pot liner', respectively. The amount of coatings, inks and compounds present in the can, as well as the oxidized portion of the metallic surface oxidized and the inherent process losses during the recycling stage were accounted for as solid waste (output).

The water used in the industrial processes that later returns to sewers or rivers was quantified, while the water of closed systems and/or internal recirculation were excluded. However, the necessary replacement water was considered (make up). When the water supply for the industry was done by the public grid, the public water treatment process was included in the boundaries.

The materials leaving the systems that were recycled by means of a process located beyond the boundaries of the study were aggregated and identified as 'open loop outputs'.

Process scraps recycled in the same production chain as the scraps originated in the sheet and foil rolling process were treated as 'closed loop recycling'.

Finally, it is important to note that the present LCA study does not include capital investments, i.e., resources and energy used for the construction and maintenance of manufacturing sites and equipment, roads, power plants, trucks, and so forth. Only the inputs and outputs directly associated with the production, distribution and disposal of the products throughout their life cycle were identified and quantified.

All the results and main conclusions were submitted to critical analysis (criteria for the evaluation of data quality).

This study was conducted in accordance with the recommendations of SETAC – Society of Environmental Toxicology and Chemistry and ISO 14040 Standard, nowadays published as Brazilian Standard [1,2,7].

ISO 14040 – Environmental management- Life cycle assessment- Principles and framework – was approved and published as International Standard in 1997. This Standard establishes the basic principles and requirements for conducting and reporting the results of Life Cycle Assessment studies; provides definitions for the main terms used in LCA studies; describes the goals and applications of the LCA technique, identifies and characterizes the different phases of an LCA study.

Data storage and modeling were performed by employing of the PIRA Environmental Management System – PEMS.

Initially the inventories regarding the production of 1,000 kg of primary aluminum and 1,000 kg of recycled aluminum were built and, afterwards, life cycle inventories of the production of 1,000 kg of cans DWI for beverages, considering different recycling rates were elaborated upon. The influence of the recycling rate on the energy and natural resources requirements and on the emission levels are presented in graphs showing the relative reduction of the main inventoried parameters. The recycling rate of 36% (w/w) corresponds to the percentage of aluminum recycled in relation to the domestic consumption of primary aluminum in 2004, while 89% (w/w) represents the rate between the amount of aluminum cans recycled to the volume of cans produced in Brazil in 2003 [4].

3 Results and Discussion

Fig. 3 to 7 present graphs illustrating the consumption reduction of natural resources and energy requirements and air and water emissions, as well as solid waste generation in the production chain of DWI aluminum cans for beverages with a capacity of 350 mL as a function of the aluminum cans recycling rate increase.

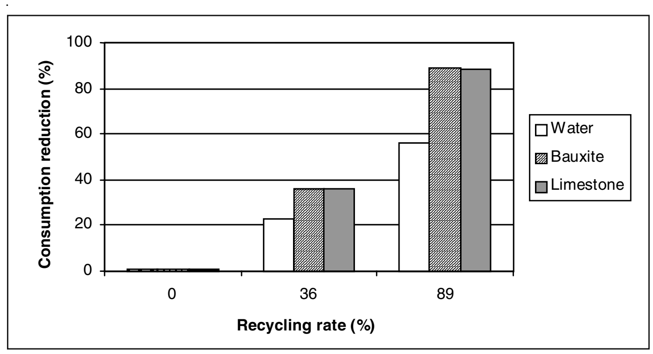

Fig. 3: Consumption reduction of natural resources in the production chain of the DWI aluminum can for beverages as a function of the increase of the recycling rate

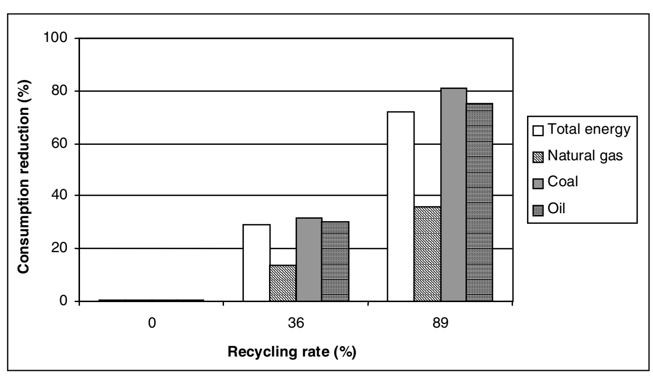

Fig. 4: Consumption reduction of Total Energy and Natural Resources in the production chain of DWI aluminum cans for beverages as a function of the recycling rate

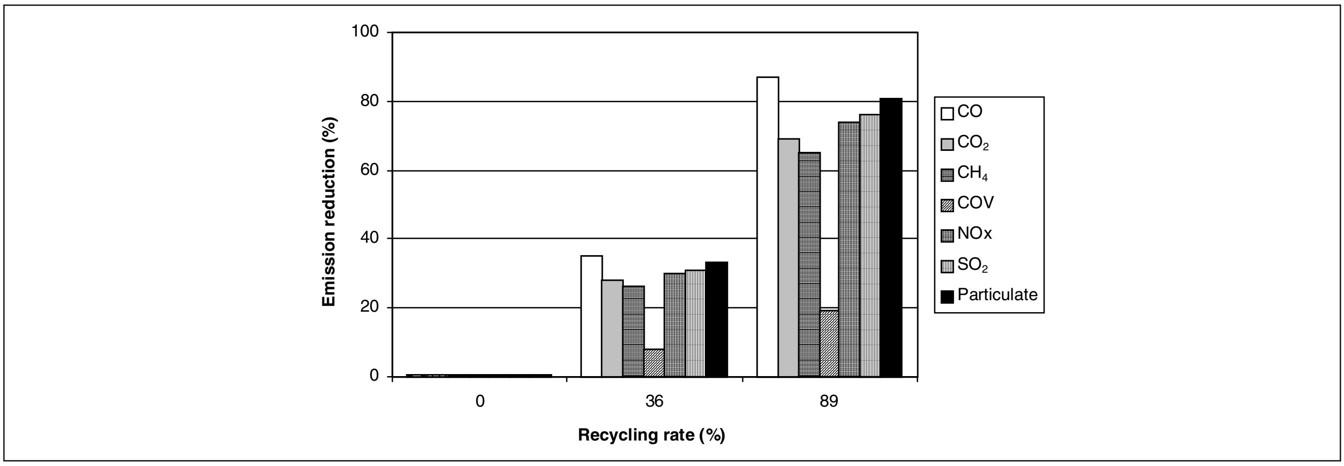

Fig. 5: Air Emission reductions in the production chain of DWI aluminum cans for beverages as a function of the recycling rate

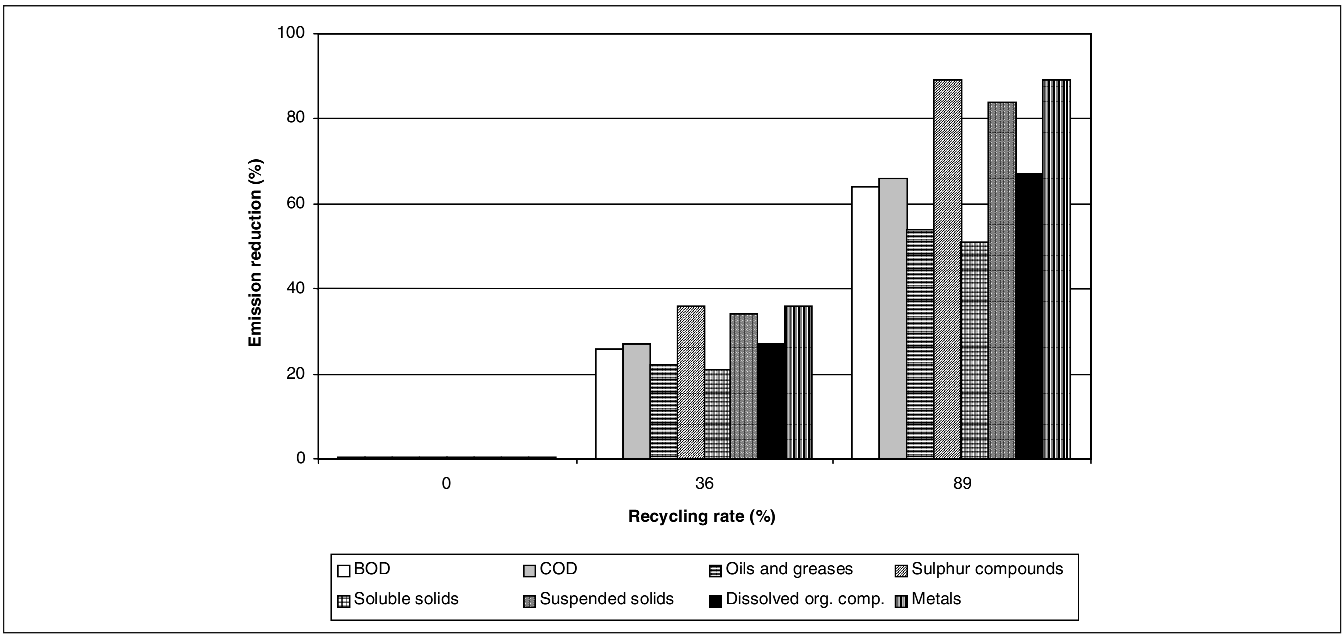

Fig. 6: Water Emission reductions in the production chain of DWI aluminum cans for beverages as a function of the recycling rate

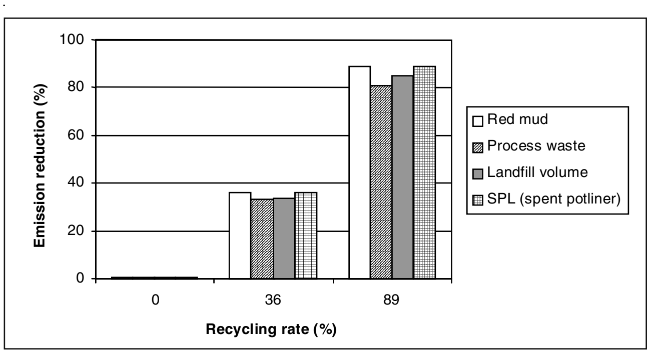

Fig. 7: Solid Waste reduction in the production chain of DWI aluminum cans for beverages as a function of the recycling rate

In general, the decrease of the natural resource consumption of bauxite, limestone and water becomes more expressive as the recycling rate increases. The decreases of the water consumption become less expressive due to the contribution of the recycled aluminum production process.

The increase of the natural resource consumption of oil, natural gas and coal becomes less expressive as the recycling rate decreases, since, in those situations, the contribution of the recycling process is important due to the profile of the energy (natural gas) employed.

Taking into account the air emissions, discounting the fraction of the imported sheet contribution, the decrease of the emissions ranged according to the increase of the recycling rate. The exceptions were the emissions of VOC, since the participation of the can coating cure is very important.

Discounting the fraction related to the imported sheet, the water emissions showed a decrease of the values as the recycling rate increase, likewise the parameters obtained during the primary aluminum production. The parameters that are also generated in other stages of the process show the increase only for the fraction relative to the aluminum production, so they do not point out such an extensive decrease.

In relation to the solid waste (process waste, red mud and SPL), as happens with the natural resources, a proportional increase in its generation is also verified due to the higher consumption of the primary aluminum.

4 Conclusions

Despite the inherent difficulty of accessing real data for LCA studies, the data representativeness of this study was outstanding, since 100% of the Brazilian aluminum industry cooperated with the project. Nevertheless, for the aluminum recycling stage, it was not possible to reach 100% representativeness, although the data collected were representative of the sector.

The influence of the aluminum recycling rate on the inventoried parameters is similar since the values increase as the recycling rate decreases, but the proportions vary according to the parameter, depending on the contribution of the primary aluminum production stage to the final values of the inventory. However, this fact is expected since the primary aluminum production predominates over almost all the other stages of the life cycle of the can.

In general, the recycling balance is always positive due to the importance of the stages that precede the packaging production and the problem of increasing the municipal waste volume. The advantages of the recycling are obviously concentrated on the parameters related to the primary aluminum production and to the package disposal. The verified benefits of the recycling increase with the recycling rate enhancement. However, the effects on the inventory do not have the same magnitude of recycling rate. This happens due to the relative contributions of the other life cycle stages, such as the transportation and sheet or can production.

In agreement with the presented results, it is possible to conclude that the aluminum can recycling reduces part of the consumption of natural resources and the emissions associated to the stages previous to the production of the packaging. The parameters specifically related to the stage of aluminum production suffer reduction directly proportional to the increase of the recycling rate. In this way, all the efforts made to increase the recycling rate will have a positive contribution on the LCI of the aluminum can.

5 Recommendations

For the environment, the goal is to reach the situation with the smallest requirements of energy and natural resources, and with the lowest emission levels possible. Thus, environmental impacts will be small and more resources will be preserved for the future generations. The simplistic rule can be applied to all the inventoried parameters. Therefore, a good performance of the system is expected in all evaluated aspects. In the same way, it is possible make improvements.

In the case of the primary aluminum and of the transformed aluminum products, can and foil, the most consumed natural resources are bauxite, petroleum, coal (all non-renewable resources) and water.

The natural resources used for an energetic purpose are also petroleum and natural gas. In Brazil, more than one half of the total energy associated with the primary aluminum are hydraulic, a renewable source, while the remaining energy is due to the use of fossil fuels (in thermal power plants, for transportation or for heat and work production).

The water emissions presented in the inventories do not allow many conclusions relative to their specific effect on the environment, since they were mainly reported as groups (BOD, COD, suspended solids, soluble solids). However, they contribute to impact categories like ecotoxicity and eutrophication.

Part of the air emissions were quantified by means of stoichiometric calculations or emission factors. This was necessary in the cases that those emissions were not informed by the industries that supplied data to the project. The data of the inventories can be optimized hereafter, replacing those values with real emission levels.

For the transformed aluminum products, the recycling rate affects the values of their inventories, but not in the same proportion, since the contribution of other stages of the product system life cycle and the recycling process yield remain unchanged.

In general, non-collected data were always estimated, taking into account available information in order to minimize the occurrence of missing data.

The collaboration of the companies was outstanding. Concerning this aspect, the project was very diverse from the great majority of this kind of study in which the main difficulty is the participation of the productive sector, since there is a certain fear in disclosing data of relative confidentiality and complexity.

In this context, the objectives of the study were considered accomplished with the available data.

It is worth pointing out that LCA studies are iterative and dynamic. The data can always be refined, substituted or complemented with more updated information, continuously representing the environmental performance of the analyzed sector better and better.

The conclusions and recommendations of an LCA solely apply to the specific, analyzed situation, in other words, they depend on the technological level, legal requirements and the material resources available in the country submitted to analysis. Any adaptation of conclusions contained in international reference sources will be necessarily vague and questionable.

This study provided with basic LCA information and models will permit further evaluation and interpretation of specific environmental situations of the aluminum sector.

6 Perspectives

It is worth pointing out that LCA studies are iterative and dynamic. The data can always be refined, substituted or complemented with updated information in order to improve the representativeness of the analyzed sector. Brazil recycled 96.2% of the total aluminum cans sold in 2005. With that index, the country stands out as the world leader in recycling [8,9]. From this study, the aluminum sector in Brazil is able to quantify the benefits of future actions for environmental improvement of the Brazilian aluminum industry, as well as to contribute technically to Environmental Labeling initiatives regarding aluminum products.

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First Announcement of the Special Issue

Life Cycle Performance of Aluminium Applications

(Int J LCA Vol. 13, Special Issue No. 1, to be published in August 2008)

Editors: Gerald Rebitzer[1] and Jörg Schäfer[2]

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The aluminium industry believes that Life Cycle Assessment is the only tool to assess the environmental performance of products. Since the very beginning, the aluminium industry has been involved in the development of Life Cycle Assessment. The ISO standards are a result out of this development and the key to conduct LCAs. In particular with respect to aluminium of a high energy demand on the primary production and the potential for energy savings during the use, distribution and recycling phases, life cycle considerations are the only option to get a balanced picture of the environmental performance of aluminium applications. The aluminium industry is proud of having the opportunity to generate a platform in the Special Edition of Int J LCA on 'Life Cycle Performance of Aluminium Applications'.

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(by a Representative of EAA – European Aluminium Association)
2) Commentary: Carbon Footprint, Labelling and LCA
Hans-Jürgen Schmidt (Hydro Aluminium Deutschland GmbH)

Life Cycle Inventory Data

3) Provision of LCI Data in the European Aluminium Industry: Methods and Examples
Christian Leroy (EAA – European Aluminium Association)
4) Experiences with the Peer Review Process of Aluminium Data
Walter Klöpffer
5) Usability of National Reporting Data as a Reference for LCI Modelling
Jens Warsen, Christian Bauer, Liselotte Schebek
(Department of Technology-Induced Material Flow, Institute for Technical Chemistry, Forschungszentrum Karlsruhe, Germany)

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7) Aluminium Cans and LCA: Situation in Germany
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8) Analysis of the Complete Food Supply System: Examples Coffee and Butter
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9) Independent Information Modules: A Powerful Tool for Life Cycle Management
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10) Life Cycle Sustainability Assessment
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